AN UPDATED LUNAR-A MISSION SCENARIO AND ITS SESMIC PENETRATOR DEVEROPMENT

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ABSTRACT - *Mission of the LUNAR-A is to have some knowledge and the information about the origin and the evolution of the moon by measuring the traveling of the seismic wave and the heat flux at the lunar surface. Seismometers and heat fluxmeters are to be boarded on the penetrator which will penetrate to the lunar surface and the data measured are to be transmitted to the ground station via mother spacecraft in the lunar orbit.*
LUNAR-A was planned to be launched in 1999. However, due to some engineering problems to be solved for the penetrator, the launch was determined to be delayed.
In this paper, the change of the configuration of the spacecraft from the original plan, the engineering problems to be solved for the penetrator and the planned process to the launch are presented.

KEYWORDS: lunar exploration, penetrator, seismometer, bi-propellant engine

INTRODUCTION

LUNAR-A was planned to be launched in the summer of 1997 with three penetrators on board.[1] However, on the process of the mechanical environmental test, some problems were found in the separation mechanism which has the function of fixing the penetrator at the period of launching and also of deploying it on the lunar orbit. Then the launch was determined to be delayed to the summer of 1999. As the result of this delay, it was found that the orbiter would experience the long eclipse six months after the insertion into the lunar orbit.

After the hard trade-off study, some additional batteries were determined to be boarded to survive this eclipse and the number of the penetrator was changed from three to two, when the moonquake originating from the source measured by Apollo's seismometer would effectively be referred. Fig.1 shows the modified configuration of LUNAR-A.

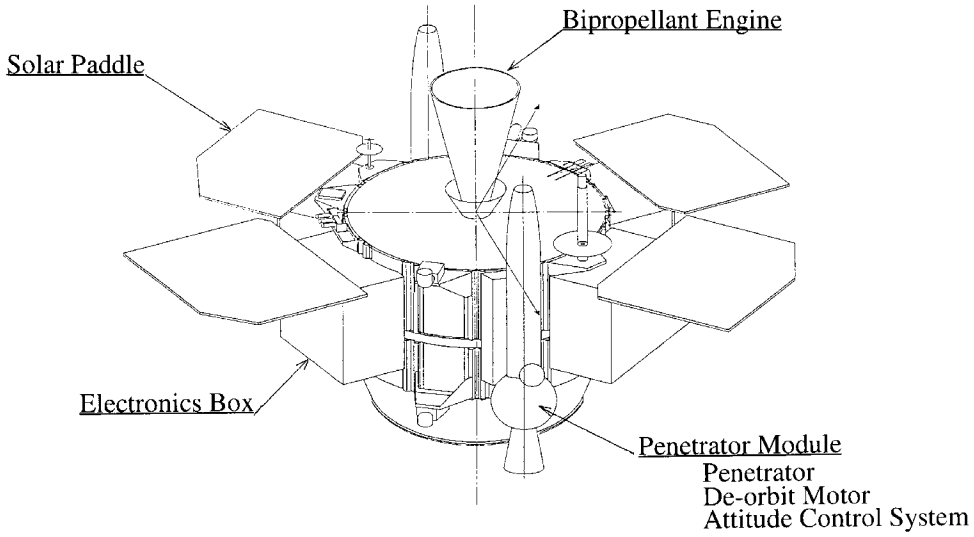

Fig. 1 LUNAR-A

In the end of 1998, the Qualification Test (QT) of the penetrator was carried out. QT model was shot into the target sand under the QT condition. After the shot, some problems were found with the electrical Ground Support Equipment (GSE) and they were concluded to be caused by the crack traveled in the encapsulating material, which was found by cutting the QT model and by investigating the inside. After the study of this problem, the launch was determined to be delayed again to the summer of 2003, in order to solve this crack problem.

In the present paper, the process of the development of LUNAR-A including the problems encountered, the progress of it and the update mission scenario are going to be presented.

MISSION OBJECTIVES

LUNAR-A Program is to have some knowledge and the information about the origin and the evolution of the moon by measuring the traveling of the seismic wave and the heat flux at the lunar surface. Originally three penetrators were planned to be penetrated to the near side, the far side and the boundary of both sides of the moon, though the number of the penetrator has been changed from three to two subsequently. Two-axis seismometer, heat flux meter, thermometer, Data Processing Unit (DPU), transmitter/receiver, battery etc. are boarded on the penetrator. (Fig.2) After penetrating to the lunar surface, when the antenna section at the rear portion of the penetrator is planned to be located at one or two meter from the lunar surface from the requirement of the measurement, data measured are to be transmitted to the ground station via mother spacecraft (lunar orbiter) in the lunar orbit.

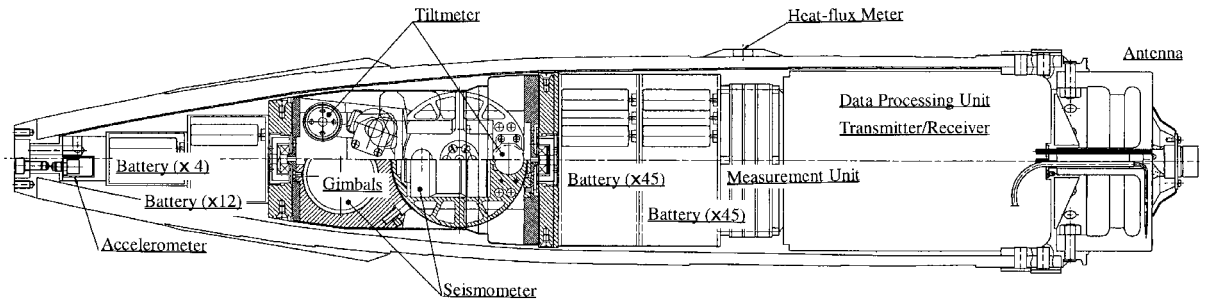

Fig. 2 Penetrator

Payload investigators believe that they will be able to have an information about the feature of the core of the moon by measuring the refraction and the reflection of the traveling of the seismic wave originating from 400 km ~ 900 km below the lunar surface. The presence of the iron rich core is the key interest of them.

They also believe that some information about the presence of such radio-thermal elements as U and Th will be obtained by measuring the heat flux conducted from the core to surface of the moon.

Optical measurement of the lunar surface is also to be carried out by the Lunar Imaging Camera (LIC) boarded on the lunar orbiter and new knowledge about the geological and topographical feature of the moon is expected to be obtained.

Engineering investigation of the applicability of the penetrator to the lunar and/or planetary exploration is another important objectives of the LUNAR-A Program.

PROGRESS OF THE PROGRAM

LUNAR-A System

LUNAR-A was planned to be launched in the summer of 1997 with three penetrators on board. Then, in the process of the mechanical environmental test, some problems were found in the separation mechanism which has the function of fixing the penetrator at the period of launching and also of deploying it on the lunar orbit. Insufficient rigidity of it caused the misalignment of the principal axis of the penetrator which would result in the increase of the angle of attack at the penetration to the lunar surface. And insufficient power of pyrotechnics caused the degradation of the reliability of the separation. The launch was determined to be delayed to the summer of 1999 to resolve these two problems.

Then, it was found that the orbiter would experience the long eclipse six months after the insertion into the lunar orbit. Without additional batteries, the mission life of LUNAR-A would be six months instead of original one year.

After the hard trade-off study, some additional batteries were determined to be boarded and the number of the penetrator was changed from three to two.

To minimize the modification, additional one solar paddle and one Electronics Box were installed around the thrust tube. (Fig.1) This modification of the system means the degradation of the quality of the scientific research. However, payload investigators believes that they would be able to accomplish the

original objectives to have a knowledge and an information about the iron-rich core of the moon, by referring the seismic wave originating from the source measured by the Apollo's seismometer.

Penetrator

IHI Aerospace Co., Ltd. (former Aerospace Division of Nissan Motor Co., Ltd.) conducted Qualification Test (QT) of the penetrator at the facility of Sandia National Laboratories (SNL) in December 1998. QT model of the penetrator was shot by the Davis Gun, when the impact velocity and the angle of attack was 323 m/s and 8.6 deg, respectively. The nominal impact velocity and the maximum angle of attack when penetrated to the lunar surface is supposed to be 300 m/s and 8.0 deg, respectively.

When inspected after the recovery from the target sand, some electrical problems were found by GSE. Access to the Measurement Unit (MSU), which controls the data sampling and arrangement measured by the seismometers, heat flux meters, thermometers and so on, was not possible. Then, the penetrator was cut to inspect what happened and some cracks which destroyed the electronics board and harness were found.

After the detailed study about the reason why such cracks were broken out, it was concluded that the difference of the thermal expansion coefficient between the outer case of the penetrator made of the CFRP and the encapsulating material filled inside of it. The temperature of the penetrator at the instant of the penetration to the lunar surface is requested to be nearly same as that of the environmental regolith, in order not to disturb the thermal environment by the penetration. The environmental temperature in the regolith is supposed to be around -20 ºC. The temperature when the encapsulating material is filled into the CFRP case is around 25 ºC. Then the penetrator does experience the temperature difference of around 45 ºC.

After the concentrated study and the discussion about how to approach and to solve this problem, new launching data was set to be in the summer of 2003.

The key problem to be solved is to improve the fragility of the encapsulating material, so that it will tolerate such temperature difference as above mentioned.[2]

Progress

Some possibility about the control of traveling of the crack and the improvement of the fragility were studied. To solve the first problem, the idea of the installation of the slit, which would control the traveling of the crack, was applied and determined to check whether it would be effective or not, by the penetration test at SNL in May 2000. The new encapsulating material applicable to the penetrator was studied and tested by the test model consisting of case of CFRP and the candidate materials, where some electronic boards and harness were installed in it.

It took about one year to find some new material considered to be applicable to the environmental conditions previously mentioned and some probes consisting of new material with and without slit were tested in the series of penetration test at SNL in May 2000.

Post-test inspection showed no harmful crack found in both probes and the probes without the slit was determined to be applied to the flight model. Quasi-qualification test of the penetrator was carried out in May, 2001 at SNL. The results were nearly satisfactory and the communication between the probe in the target sand and the hat-antenna of the GSE, which simulates the orbiter, was successfully established.

Based on the latest results, the QT of the penetrator is planned to be carried out in August 2002 and the

LUNAR-A is scheduled to be launched in the summer of 2003, presently.

MISSION SCENARIO

Fig. 3 shows the updated mission scenario of the LUNAR-A. The scenario is changed from the previous one, which was the nearly six months flight from the launch to the insertion to the lunar orbit. In the updated one, nearly ten months flight is planned, which was determined to pass the eclipse encountered if six months ones are applied.

More detailed orbit design is underway to save the fuel necessary for ΔVs.

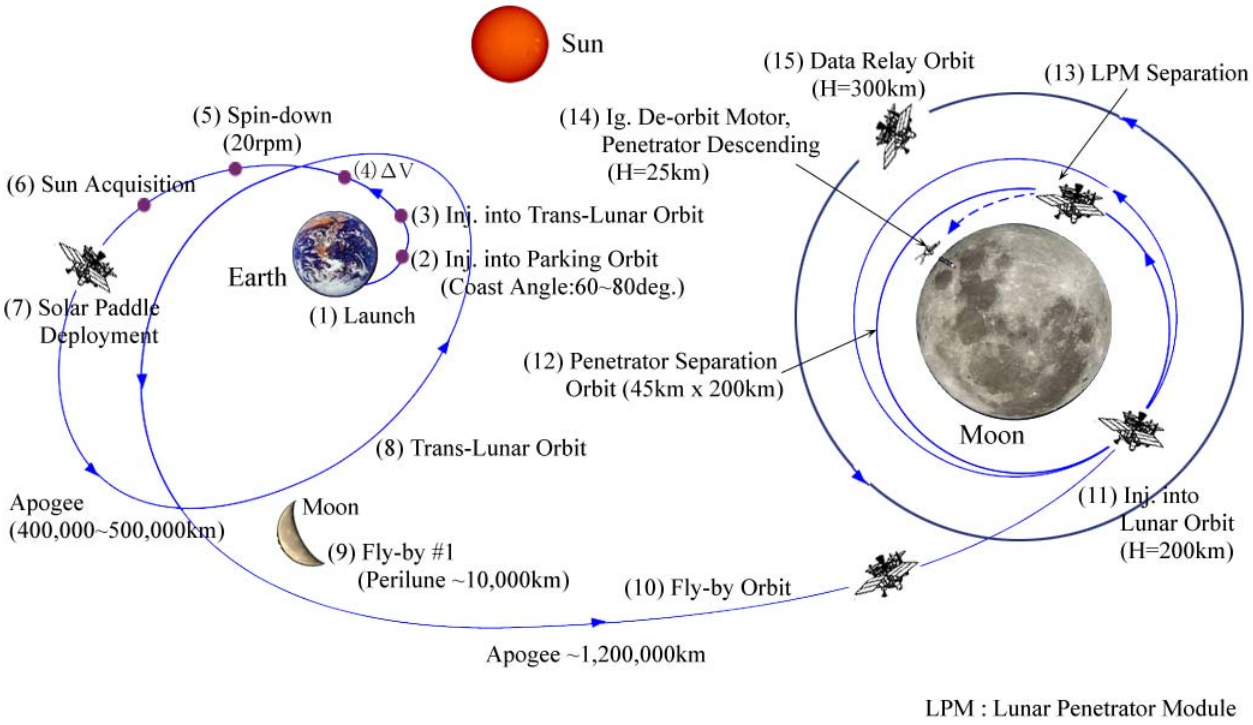

Fig. 3. Mission Scenario

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